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LABORATORY EVALUATION OF NARROW FABRICS  
WOVEN ON SHUTTLELESS LOOMS

by

Joseph W. Gardella  
Vasant K. Devarakonda

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this task was to determine the relative mechanical properties of comparable webbings woven on shuttleless looms and shuttle looms. The tensile properties, lateral curvature, abrasion resistance and high speed impact properties of comparable narrow fabrics woven on shuttleless and shuttle looms were determined. It is demonstrated that shuttleless webbings compare favorably to shuttle webbings in all properties measured.														

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## PREFACE

In the continuing effort towards the utilization of new technologies to broaden the base of supply and improve the cost effectiveness of military textiles, the Textile Research and Engineering Division initiated this study to characterize and compare a series of standard webbings to similar webbings manufactured on shuttleless looms.

This project was conducted under the Production Engineering program, Task 23, Project 4, Textile, Leather, Rubber and Plastics and covered the period from March 1977 to May 1978.

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## LABORATORY EVALUATION OF NARROW FABRICS WOVEN ON SHUTTLELESS LOOMS

### INTRODUCTION

It is becoming increasingly apparent that a change is occurring in the narrow fabrics industry in the United States. Webbing manufacturers are investing more capital in shuttleless weaving equipment than they are in conventional shuttle looms. It has already been established that the European webbing manufacturers have, for the most part, converted to shuttleless looms.

The webbings that are currently used in US military life support and airdrop delivery systems are woven exclusively on shuttle looms. In fact, the technical requirements of webbing specifications for these end uses do not permit production on shuttleless looms.

Discussions with personnel of webbing manufacturers indicate that there is very good reason to feel that the trend to shuttleless looms in the United States will continue and accelerate in the near future. In order to broaden the base of supply of webbing capabilities and, at the same time, determine the cost advantage, if any, in using shuttleless webbings, action must be taken to consider the use of shuttleless webbings for life support and airdrop delivery systems.

Webbings used by the US Army, whether employed as parachute components, tiedown straps, or for miscellaneous uses are rarely designed for one-time load applications. Useful service life usually depends upon a webbing's ability to withstand abrasive wear continuously in conjunction with tensile loads and flexing. An important aspect of abrasion resistance is the ability to resist wear at buckles, over guides, at seams, and at hardware attachments.

The airdropping of personnel or equipment by parachute involves the engagement of an array of hardware with suitable reinforcing members within the parachute structure. Many parachute designs are currently used in the airdropping of personnel or equipment, all having in common the use of nylon webbing as load-bearing members. These webbings are subject to: high temperature and pressure during the pressure packing of the parachute; a space environment of low ambient pressure and temperature up to, and for some time after, deployment; and the severe loading conditions during parachute opening. Experience with currently used standard nylon shuttle webbings has indicated that they are suitable for airdropping personnel and equipment since they are nominally capable of withstanding the loads imposed on them. Now, a new family of nylon webbings has entered into the textile marketplace. These webbings, woven on shuttleless looms, have been evaluated for military applications in noncritical uses and are, in fact, currently being used by the military; however, as mentioned above, none are being used in critical (life supporting) applications. Accordingly, a laboratory study has been carried out on the behavior of critical use nylon webbings woven on shuttleless looms.

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LABORATORY EVALUATION OF PARACHUTE WEBBINGS

It is recognized that during the course of an airdrop, the load bearing webbings are subjected to a succession of potentially harmful conditions which are difficult to measure in the laboratory. These are: high-speed webbing-on-metal abrasion; high-speed webbing-on-webbing abrasion; high-speed tensile loading; and loading conditions of unknown characteristics resulting from the lift, drag and gravitational forces on the payload and parachute. While all of these conditions are considered as being very important and worthy of investigation, no attempt was made in this study to characterize the test webbings for these conditions. The objective of this task was to determine the relative mechanical properties of comparable webbings woven on shuttleless looms and shuttle looms. Details of the webbing constructions, the test procedures, the experimental results and the interpretation of the results are given in the following sections.

## MATERIALS

The Aero-Mechanical Engineering Laboratory supplied a list of 16 nylon webbings which are currently being used in critical applications. From this list, six webbings were chosen to be used in this study. The intent was to evaluate as broad a range of breaking strengths as possible.

The six standard (or control) webbings included in this investigation were from Military Specification MIL-W-4088H, Webbing, Textile, Woven Nylon. All standard webbings were dyed to Olive Drab (OD) No. 7 shade and resin impregnated as described in Military Specification MIL-W-27265C, Webbing, Textile, Woven Nylon impregnated. The physical and mechanical requirements of the six standard webbings are given in Table 1.

The six standard webbings were furnished by three manufacturers. Types I and XII were purchased from Bally Ribbon Mills, Bally, PA. Types VI, VIII, and XIII were purchased from Murdock Webbing Company, Central Falls, RI. Type XXII was supplied by Southern Weaving Company, Greenville, SC. All standard webbings were furnished from inventory and represent typical production.

The basic differences of webbings woven on shuttleless looms are that two filling picks are inserted in each shed and the filling is held at one edge of the webbing by a catch-cord end interlacing (knitting) with the filling yarn in a method depicted in Figure 1. Inserting two picks per shed makes it necessary to use half the required filling yarn size (denier) when weaving on shuttleless units. All other constructional variables of the shuttleless webbings are similar to the standard webbings.

The six shuttleless test webbings were purchased from Elizabeth Webbing Mills, Central Falls, RI. The webbings were designed and woven to the same specification requirements as the standard webbings, were dyed to OD-7 shade, and resin-impregnated per MIL-W-27265C. The Type XXII test webbing was inadvertently supplied without a catch-cord end interlacing with the filling. While this is not recommended as standard procedure, it was recognized during evaluation and had no influence on the laboratory testing. Both the standard and test webbings were characterized for their physical properties and these are given in Tables 2 and 3, respectively.

The weave for Types I, VI, VIII, and XII was a 2 x 2 herringbone twill with one reversal at the center of the webbing. The weave for Type XIII was a double plain weave with the warp yarns weaving two ends as one. Separate binder ends were woven 2 x 2 and one end as one. The weave for Type XXII was as shown in Figure 2.

TABLE 1

Physical and Mechanical Requirements for MIL-W-4088H Webblings\*

Type	I	VI	VIII	XII	XIII	XXII
Width (in.)	9/16 ± 1/32	1-23/32 ± 1/16	1-23/32 ± 1/16	1-23/32 ± 1/16	1-23/32 ± 3/32	1-23/32 ± 3/32
Thickness (in.) (min)	0.025	0.030	0.040	0.025	0.080	0.090
(max)	0.040	0.050	0.070	0.040	0.120	0.120
Weight (oz/lin yd) (max)	0.28	1.15	1.60	0.85	2.90	3.50
Singles Yarn Size (denier)						
Warp	420	840	840	420	840	840
Binder	-	-	-	-	840	-
Filling	840	840	840	840	840	840
Yarn Ply/Ply Twist (tpi) (min)						
Warp	1/2½	2/2½	2/2½	1/2½	2/2½	3/1½
Binder	-	-	-	-	1/1½	-
Filling	1/2½	2/2½	2/2½	1/2½	2/2½	2/1½
Warp Ends (total) (min)	92	114	166	266	281	259
Binder Ends (total) (min)	-	-	-	-	34	-
Filling Ends (per in.) (min)	34	21	18	34	24	18
Breaking Strength (lb) (min)	500	2500	3600	1200	6500	9500

\* Metric units not shown. These data were extracted "as is" from the specification.



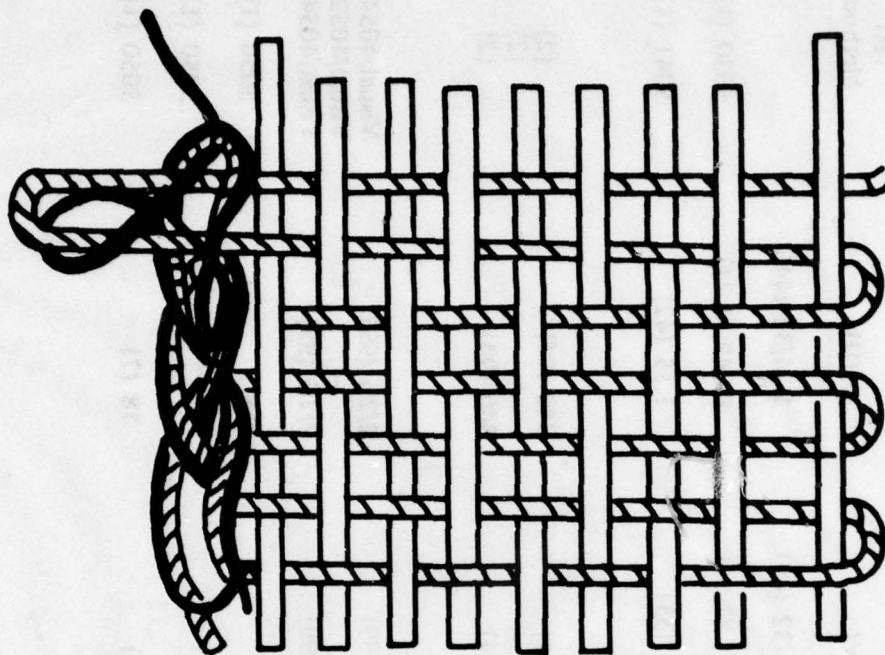


FIGURE 1. CATCH-CORD DIAGRAM



TABLE 2

## Physical Properties of Standard Webbing

Type	I	VI	VIII	Test Method
Width, in. (mm)	9/16 (14)	1-24/32 (44)	1-24/32 (44)	
Thickness, in. (mm)	0.32 (0.81)	0.045 (1.14)	0.049 (1.24)	5030 (1)
Weight, oz/lin yd (g/m)	0.26 (8)	1.08 (33)	1.35 (42)	5041 (1)
Singles Yarn Size, denier (tex)				
Warp	420 (47)	840 (94)	840 (94)	(2)
Binder	-	-	-	(2)
Filling	840 (94)	840 (94)	840 (94)	(2)
Yarn Ply/Ply Twist, tpi (tpm)				
Warp	1 1/2 (99)	2 1/2 (99)	2 1/2 (99)	Visual/4054 (1)
Binder	-	-	-	Visual/4052 (1)
Filling	1 1/2 (99)	2 1/2 (99)	2 1/2 (99)	Visual/4054 (1)
Warp Ends, total	92	114	168	5050 (1)
Binder Ends, total	-	-	-	5050 (1)
Filling Ends, per in. (per cm)	35 (14)	23 (9)	18 (7)	5050 (1)

(1) From Federal Standard 191

(2) Certificate of compliance from supplier

TABLE 2 (Cont'd)

## Physical Properties of Standard Webbing

Type	XII	XIII	XXII	Test Method
Width, in. (mm)	1-24/32 (44)	1-24/32 (44)	1-24/32 (44)	
Thickness, in. (mm)	0.033 (0.84)	0.087 (2.21)	0.105 (2.67)	5030 (1)
Weight, oz/lin yd (g/m)	0.76 (24)	2.45 (76)	3.02 (94)	5041 (1)
Singles Yarn Size, denier (tex)				
Warp	420 (47)	840 (94)	840 (94)	(2)
Binder	-	840 (94)	-	(2)
Filling	840 (94)	840 (94)	840 (94)	(2)
Yarn Ply/Ply Twist, tpi (tpm)				
Warp	1/2½ (99)	2/2½ (99)	3/1½ (59)	Visual/4054 (1)
Binder	-	1/2½ (99)	-	Visual/4054 (1)
Filling	1/2½ (99)	2/2½ (99)	2/1½ (59)	Visual/4054 (1)
Warp Ends, total	268	281	259	5050 (1)
Binder Ends, total	-	34	-	5050 (1)
Filling Ends, per in. (per cm)	36 (14)	26 (10)	20 (8)	5050 (1)

(1) From Federal Standard 191

(2) Certificate of compliance from supplier

TABLE 3

## Physical Properties of Test Webbing

Type	I	VI	VIII	Test Method
Width, in. (mm)	9/16 (14)	1-24/32 (44)	1-24/32 (44)	
Thickness, in. (mm)	0.28 (0.71)	0.041 (1.04)	0.47 (1.19)	5030 (1)
Weight, oz/lin yd (g/m)	0.24 (7)	1.06 (33)	1.41 (44)	5041 (1)
Singles Yarn Size, denier (tex)				
Warp	420 (47)	840 (94)	840 (94)	(2)
Binder	-	-	-	(2)
Filling	420 (47)	840 (94)	840 (94)	(2)
Yarn Ply/Yarn Twist, tpi (tpm)				
Warp	1 1/2 (99)	2 1/2 (99)	2 1/2 (99)	Visual/4054 (1)
Binder	-	-	-	Visual/4054 (1)
Filling	1 1/2 (99)	1 1/2 (99)	1 1/2 (99)	Visual/4054 (1)
Warp Ends, total	92	114	168	5050 (1)
Binder Ends, total	-	-	-	5050 (1)
Filling Ends, per in. (per cm) (3)	66 (26)	42 (17)	36 (14)	5050 (1)

(1) From Federal Standard 191

(2) Certificate of compliance from supplier

(3) Two picks per shed



TABLE 3 (Cont'd)

## Physical Properties of Test Webbing

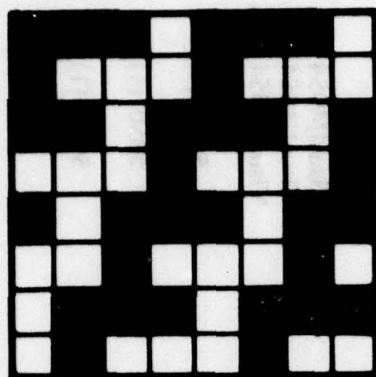
Type	XII	XIII	XXII	Test Method
Width, in. (mm)	1-24/32 (44)	1-24/32 (44)	1-24/32 (44)	
Thickness, in. (mm)	0.028 (0.71)	0.084 (2.13)	0.096 (2.44)	5030 (1)
Weight, oz/lin yd (g/m)	0.58 (18)	2.45 (76)	2.99 (93)	5041 (1)
Singles Yarn Size, denier (tex)				
Warp	420 (47)	840 (94)	840 (94)	(2)
Binder	-	840 (94)	-	(2)
Filling	420 (47)	840 (94)	840 (94)	(2)
Yarn Ply/Yarn Twist, tpi (tpm)				
Warp	1/2½ (99)	2/2½ (99)	3/1½ (59)	Visual/4054 (1)
Binder	-	1/1½ (59)	-	Visual/4054 (1)
Filling	1/2½ (99)	1/2½ (99)	1/1½ (59)	Visual/4054 (1)
Warp Ends, total	268	281	264	5050 (1)
Binder Ends, total	-	34	-	5050 (1)
Filling Ends, per in. (per cm) (3)	68 (27)	48 (19)	36 (14)	5050 (1)

(1) From Federal Standard 191

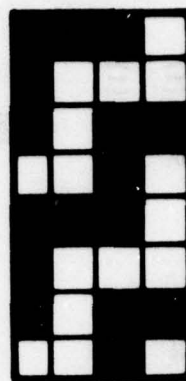
(2) Certificate of compliance from supplier

(3) Two picks per shed





**BODY**



**SELVAGE**

**BODY WEAVE: 1/3 TWILL WITH THE BACK FILLING.  
TWO ENDS WEAVING AS ONE.**

**SELVAGE WEAVE: DOUBLE PLAIN WEAVE. FIVE ENDS  
ON ONE EDGE; SIX ENDS ON OTHER  
EDGE; ONE END WEAVING AS ONE.**

**FIGURE 2. WEAWE DIAGRAM TYPE XXII.**

## TEST PROCEDURES

All standard and test webbings in this study were characterized for their breaking strength, breaking elongation and energy absorption properties according to the following procedures.

The test specimens were a minimum length of 54 inches (140 cm) and full width.

The tensile testing apparatus used was a constant rate of extension unit (Instron). The jaw speed was 2 inches per minute (50 mm/min) and the clamps used were Instron webbing capstan grips. A load cell (GR cell) of 20,000 pounds (89000 N) maximum capacity was used in testing all specimens.

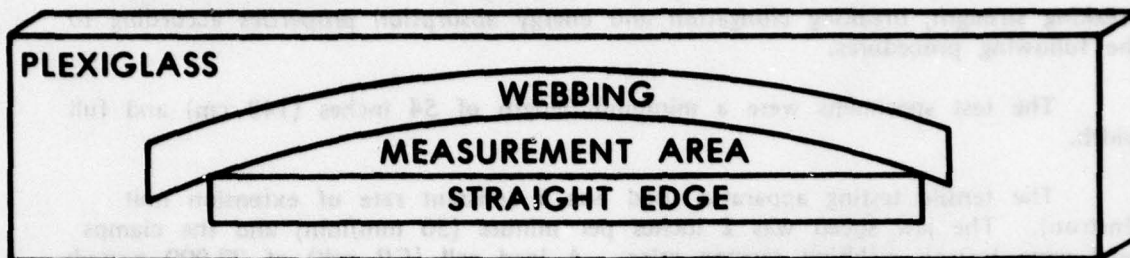
The test specimens were conditioned at 70°F (21°C), 65% RH for a minimum of 24 hours before testing. Two fine gage marks were placed on the specimens spaced 100 millimeters apart. The marks were placed in such a manner that neither was closer than 1½ inches to each clamp when the specimens were mounted in the clamps. Elongation was determined on the same specimens being tested for breaking strength. The distance between the two gage marks was measured and recorded photographically at specific load levels without stopping the equipment.

Three specimens were tested for each of the standard and test webbings. The breaking loads, breaking elongations, and elongations at specific load levels of the sample units were averaged. Average load-elongation curves for the standard and test webbings were plotted. From the average load-elongation curves, energy absorption (area under the load-elongation curve) values were determined using the planimeter technique.

The test specimens for measurement of lateral curvature were 36 inches (91 cm) in length, full width and were not stretched, smoothed, or otherwise changed from their original conditions prior to testing.

The specimens were placed flat, on a smooth, horizontal surface without tension and allowed to reach equilibrium at 70°F (21°C), 65% RH. After conditioning for a minimum of 24 hours, a weight was placed at one end of the webbing. A 1-inch (25-mm) diameter roller, weighing 1½ pounds (680 g) was placed on the specimen at the end of the webbing where the weight was located. The specimen was placed approximately in the center of the roller. The roller was rolled along the length of the specimen, care taken to keep the specimen in the center of the roller and not to exert any pressure on the roller. When the roller passed the length of the specimen, a 45-inches x 5-inches x ¼-inch (1150 x 125 x 6 mm) plexiglass panel, weighing approximately 35 ounces (1000 g) was placed on the specimen for a period of one hour.

Without moving the plexiglass on the specimen, a straight edge was placed on the plexiglass so that both ends of the straight edge were aligned perpendicularly with the outermost edge of the specimen. The highest degree of curvature of the specimen was determined from the straight edge by measuring to the nearest 1/32 inch (1 mm) perpendicularly from the straight edge. Figure 3 is a schematic diagram of the curvature measuring device.



**FIGURE 3 SCHEMATIC OF CURVATURE MEASUREMENT DEVICE**



The webbing abrasion tests were conducted on an apparatus as described in Federal Standard 191, Textile Test Methods, Test Method 5309. It consisted of a drum having a 16-inch (406-mm) outside diameter and a crank and crank arm attached in such a manner that when the specimen was attached, it oscillated the required distance and at the required rate over an abrasive surface (Figure 4).

The test specimens were a minimum length of 54 inches (140 cm), full width and were conditioned at 70°F (21°C), 65% RH for a minimum of 24 hours before testing. A weight was attached to one end of the specimen and the free end was passed over an hexagonal rod and attached to the drum. A 5-pound (2.3-kg) load was used on all test specimens except Type I standard and Type I test specimens. A 2-pound (0.9-kg) load was used on these specimens.

The hexagonal rod (abrasive surface) was steel with a Rockwell hardness of B-100 and measured ¼ inch (6 mm) across opposite flat sides. The radius of the edges was 0.02 inch (0.51 mm). The specimens were placed on the apparatus so that an angle of 85° was formed when passed over the hexagonal rod. No abrading edge of the rod was used for more than one specimen.

The drum was oscillated so that the specimen was given a 12-inch (300-mm) traverse over the rod at the rate of 60 strokes per minute for 5000 strokes. The specimens were tensile tested after being abraded according to procedures described previously.

The webbing impact tester used in this investigation is shown schematically in Figure 5. The specimen to be impacted is folded in the shape of a "V" and fastened to the rear of Pendulum No. 1. A missile whose mass can be varied from 0.5 (225 g) to 10 pounds (4500 g) is propelled from a helium operated gun, through an opening in the first pendulum, striking and rupturing the sample. The deflection of Pendulum No. 1 resulting from the impact can be measured. After breaking the specimen, the projectile enters and is contained in Pendulum No. 2. The deflection of this pendulum can also be recorded.

Knowing the period and displacement of the second pendulum, the residual velocity of the missile can be calculated. Similarly, knowing the period and displacement of the first pendulum, the loss in missile velocity as a result of specimen rupture can be determined. Having measured the residual velocity and the velocity loss, it is possible to determine the striking velocity from a summation of the two known quantities. Impact energy absorption by the specimen can then be calculated knowing the mass of the missile and its initial and final velocities from the equation:

$$E = \frac{1}{2} M(V_S^2 - V_R^2)$$

where

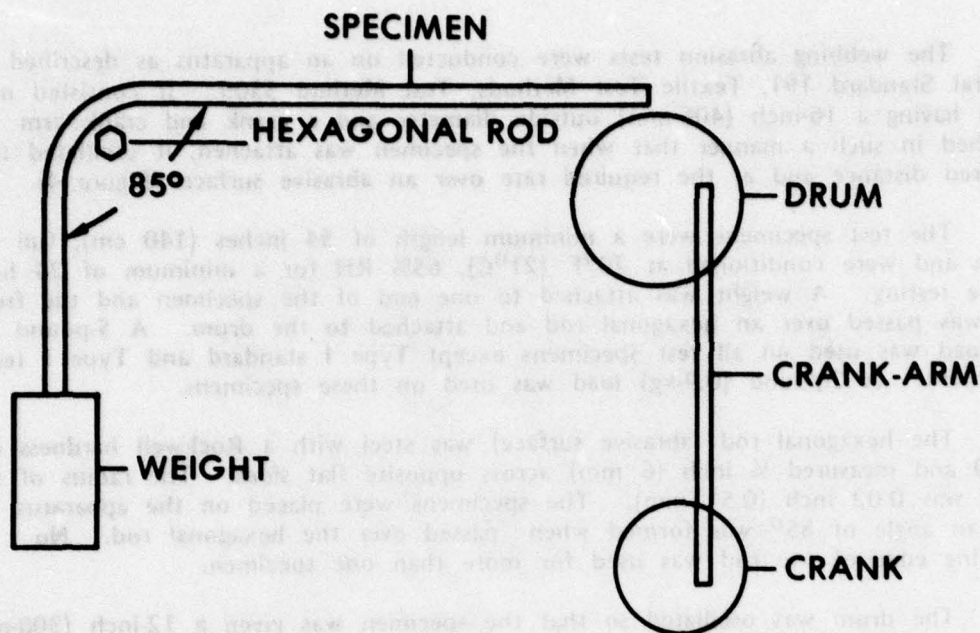
E is the total energy absorbed in rupturing the specimen,

M is the mass of the projectile,

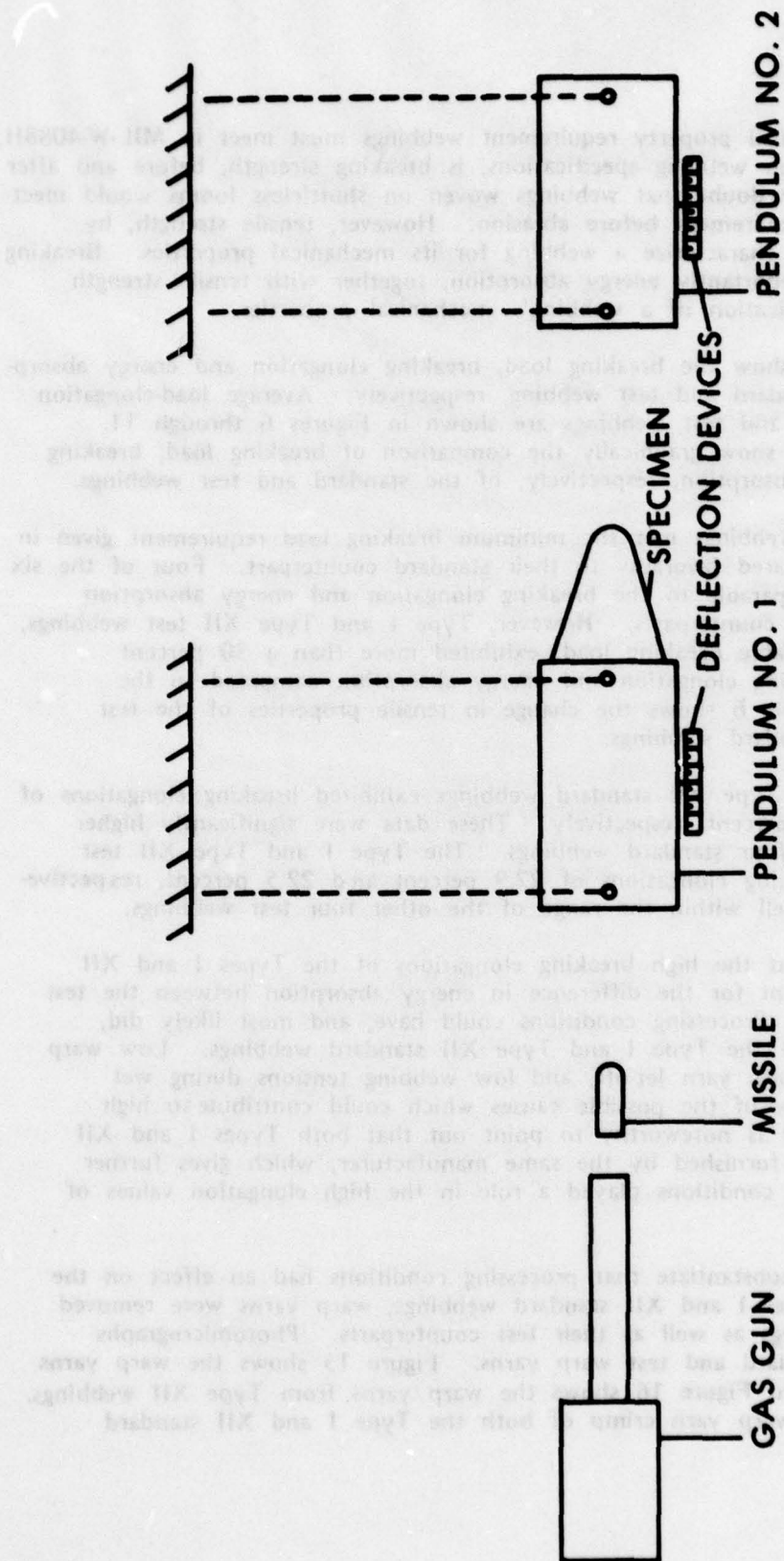
V<sub>S</sub> is the projectile striking velocity, and

V<sub>R</sub> is the projectile residual velocity.





**FIGURE 4 SCHEMATIC OF ABRASION APPARATUS**



**FIGURE 5 SCHEMATIC DIAGRAM OF IMPACT TESTING MACHINE**

## DISCUSSION

The only mechanical property requirement webbings must meet in MIL-W-4088H, as well as in other nylon webbing specifications, is breaking strength, before and after abrasion. There is little doubt that webbings woven on shuttleless looms would meet the breaking strength requirement before abrasion. However, tensile strength, by itself, is not enough to characterize a webbing for its mechanical properties. Breaking elongation, and more importantly energy absorption, together with tensile strength gives a much better indication of a webbing's mechanical properties.

Tables 4 and 5 show the breaking load, breaking elongation and energy absorption values of each standard and test webbing, respectively. Average load-elongation curves for the standard and test webbings are shown in Figures 6 through 11. Figures 12, 13, and 14 show graphically the comparison of breaking load, breaking elongation and energy absorption, respectively, of the standard and test webbings.

All of the test webbings met the minimum breaking load requirement given in MIL-W-4088H and compared favorably to their standard counterpart. Four of the six test webbings were comparable to the breaking elongation and energy absorption values of their standard counterparts. However, Type I and Type XII test webbings, while showing a comparable breaking load, exhibited more than a 30 percent reduction in both breaking elongation and energy absorption compared to the standard webbings. Table 6 shows the change in tensile properties of the test webbings versus the standard webbings.

The Type I and Type XII standard webbings exhibited breaking elongations of 33.9 percent and 34.8 percent, respectively. These data were significantly higher than any of the other four standard webbings. The Type I and Type XII test webbings exhibited breaking elongations of 22.9 percent and 22.5 percent, respectively. These data were well within the range of the other four test webbings.

It is apparent that the high breaking elongations of the Types I and XII standard webbings account for the difference in energy absorption between the test and standard webbings. Processing conditions could have, and most likely did, affect the elongations of the Type I and Type XII standard webbings. Low warp yarn tensions, uneven warp yarn let-off, and low webbing tensions during wet processing are but a few of the possible causes which could contribute to high breaking elongations. It is noteworthy to point out that both Types I and XII standard webbings were furnished by the same manufacturer, which gives further evidence that processing conditions played a role in the high elongation values of these webbings.

In an effort to substantiate that processing conditions had an effect on the high elongations of Types I and XII standard webbings, warp yarns were removed from both these webbings as well as their test counterparts. Photomicrographs were taken of the standard and test warp yarns. Figure 15 shows the warp yarns for Type I webbings and Figure 16 shows the warp yarns from Type XII webbings. It is obvious that the warp yarn crimp of both the Type I and XII standard



TABLE 4

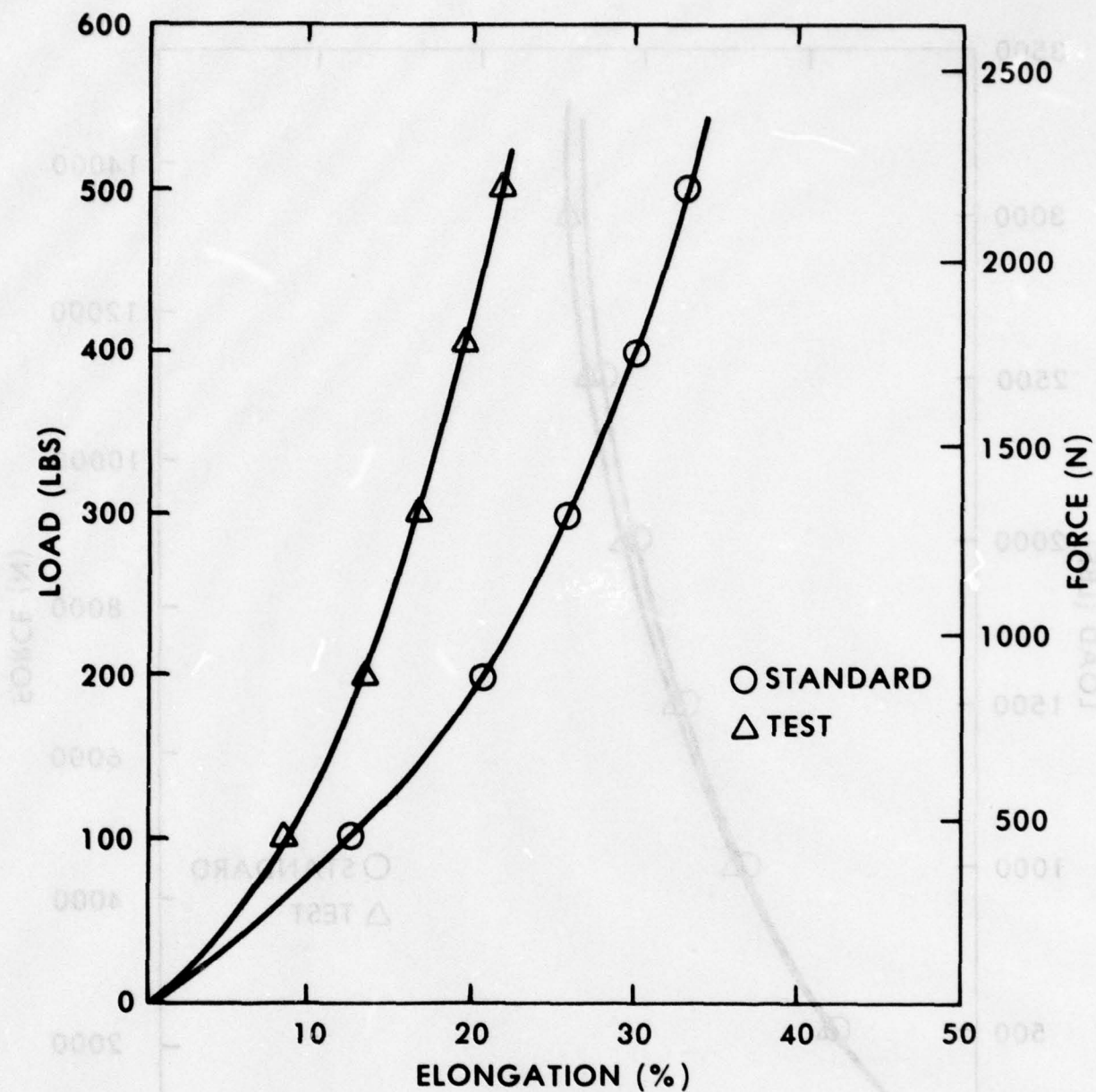
## Tensile Properties of Standard Webbing

Webbing Type	Breaking Load lb (N)	Breaking Elongation %	Energy Absorption ft lb/ft (J/m)
I	550	34.8	66.3 (295)
	550	33.5	
	560	33.5	
	Average 553 (2460)	33.9	
VI	3350	23.2	253.1 (1126)
	3300	24.4	
	3250	24.4	
	Average 3300 (14680)	24.0	
VIII	4900	22.8	383.0 (1704)
	4800	24.8	
	4700	23.8	
	Average 4800 (21360)	23.8	
XII	1580	34.8	188.0 (836)
	1580	34.3	
	1560	35.3	
	Average 1573 (7000)	34.8	
XIII	8400	27.7	711.6 (3165)
	8500	28.2	
	8100	28.2	
	Average 8330 (37070)	28.0	
XXII	10000	28.0	1010.4 (4494)
	9500	25.6	
	10500	26.8	
	Average 10000 (44500)	26.8	

TABLE 5

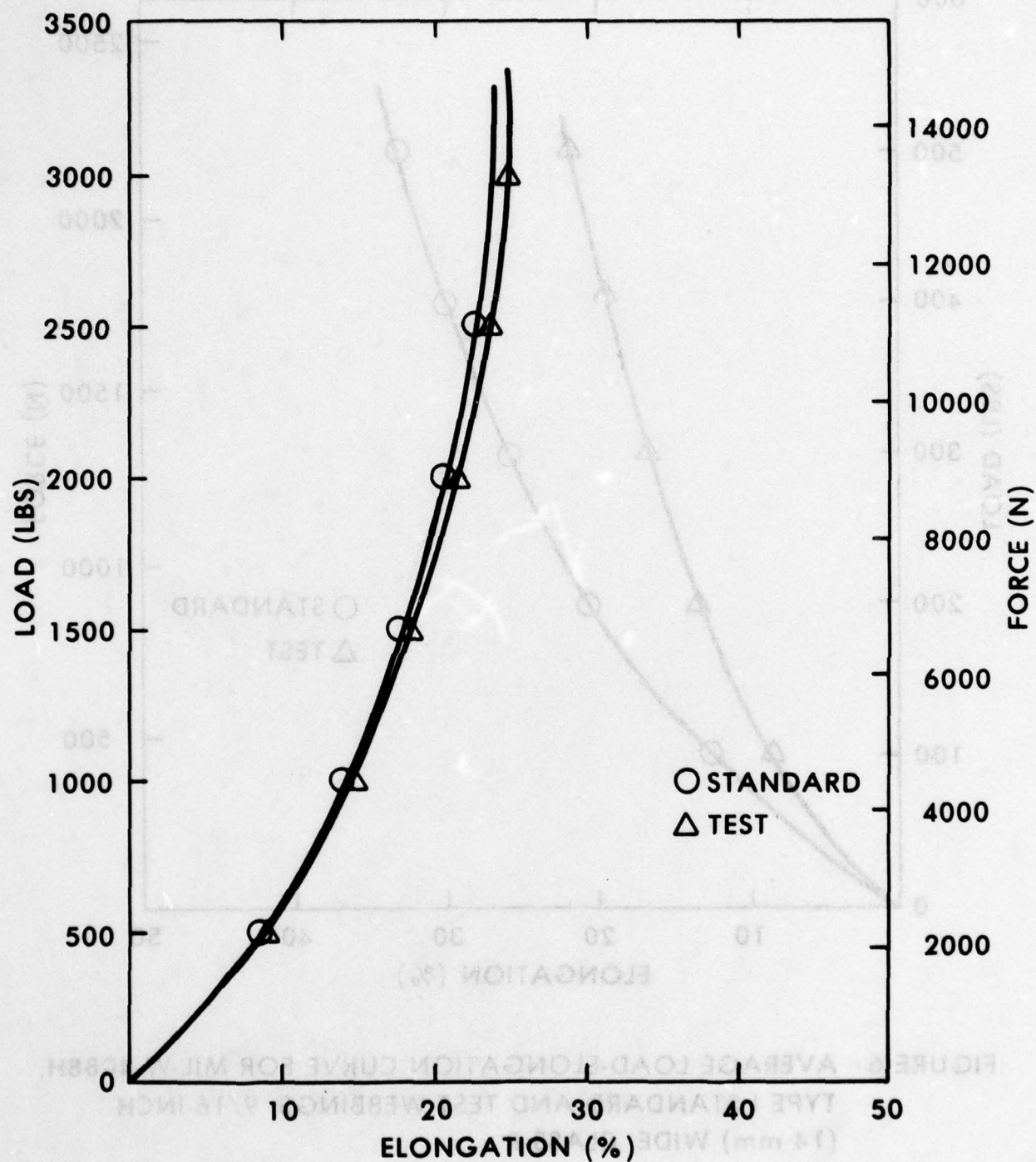
## Tensile Properties of Test Webbing

Webbing Type	Breaking Load lb (N)	Breaking Elongation %	Energy Absorption ft lb/ft (J/m)
I	530	22.9	
	530	22.9	
	530	22.9	
	Average 530 (2360)	22.9	46.6 (207)
VI	3400	24.4	
	3450	26.4	
	3500	25.9	
	Average 3450 (15350)	25.5	260.5 (1159)
VIII	4200	25.3	
	4600	25.3	
	4500	25.8	
	Average 4433 (19730)	25.5	383.8 (1707)
XII	1360	22.5	
	1380	22.7	
	1320	22.2	
	Average 1353 (6020)	22.5	112.2 (499)
XIII	8300	27.2	
	8400	27.2	
	7900	26.7	
	Average 8200 (36490)	27.0	772.7 (3437)
XXII	11350	27.6	
	12000	25.8	
	11900	25.2	
	Average 11750 (52290)	26.2	987.5 (4393)

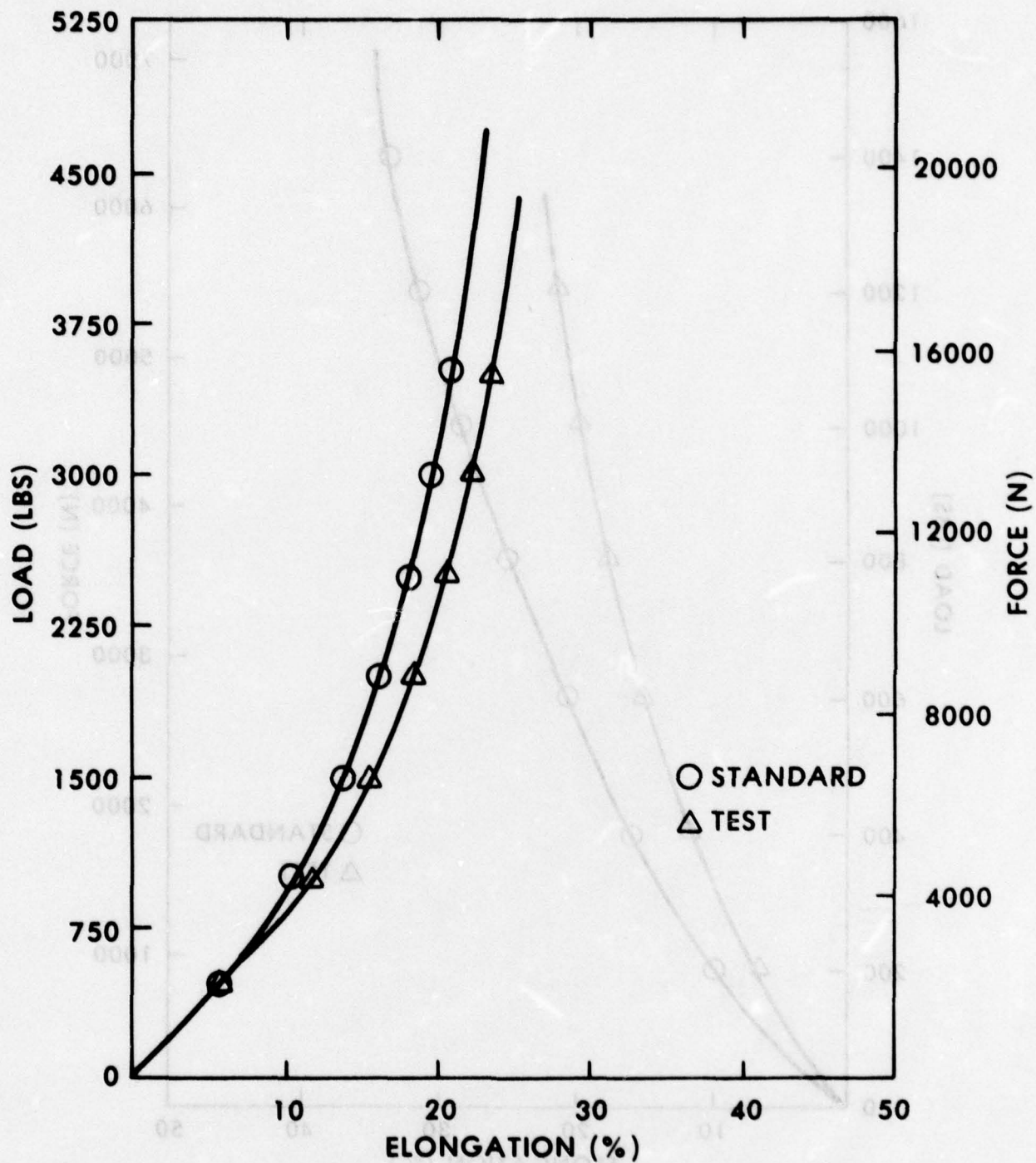


**FIGURE 6 AVERAGE LOAD-ELONGATION CURVE FOR MIL-W-4088H, TYPE I STANDARD AND TEST WEBBINGS, 9/16-INCH (14 mm) WIDE, CLASS R**

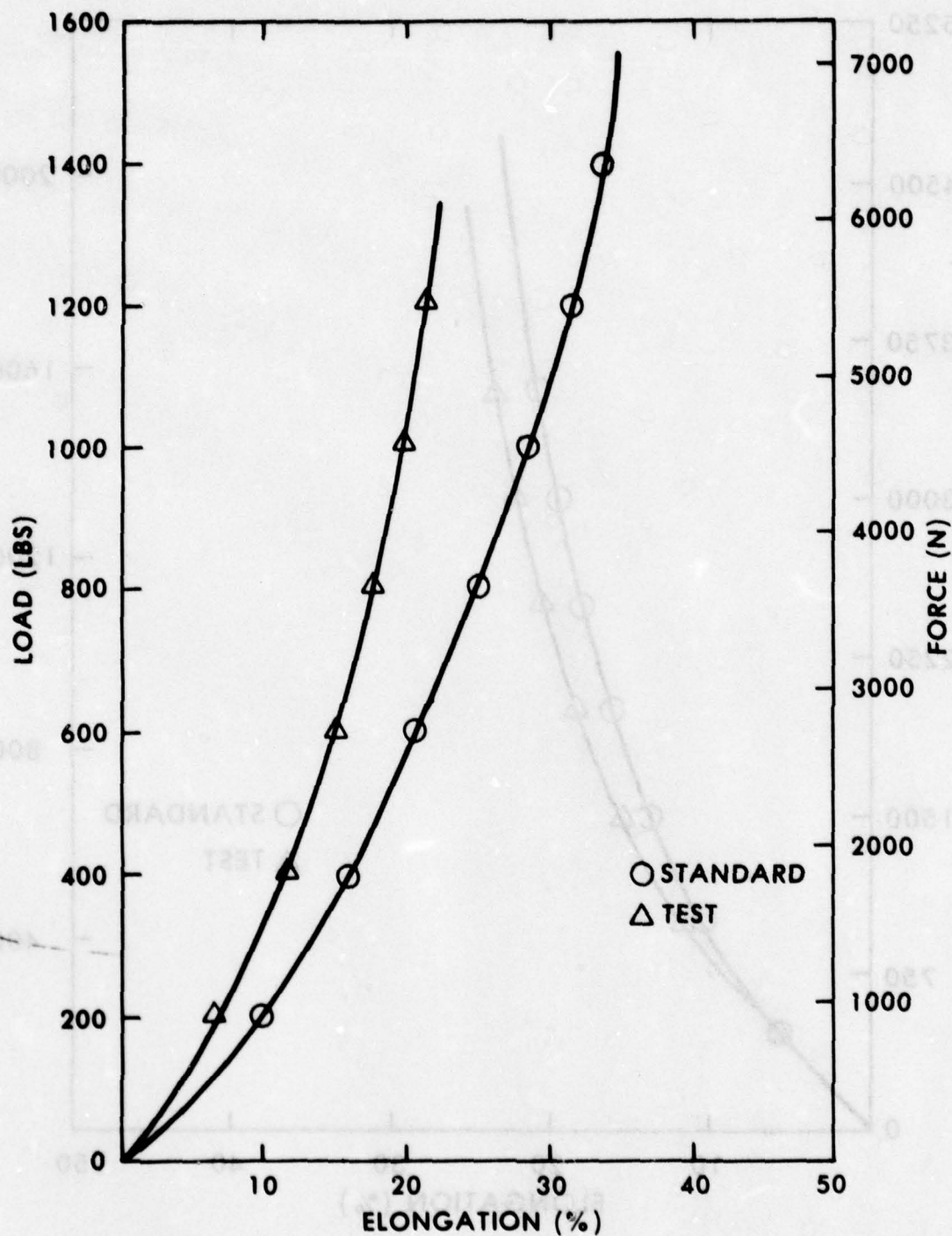




**FIGURE 7 AVERAGE LOAD-ELONGATION CURVE FOR MIL-W-4088H, TYPE VI STANDARD AND TEST WEBBINGS, 1 3/4-INCH (44 mm) WIDE, CLASS R**

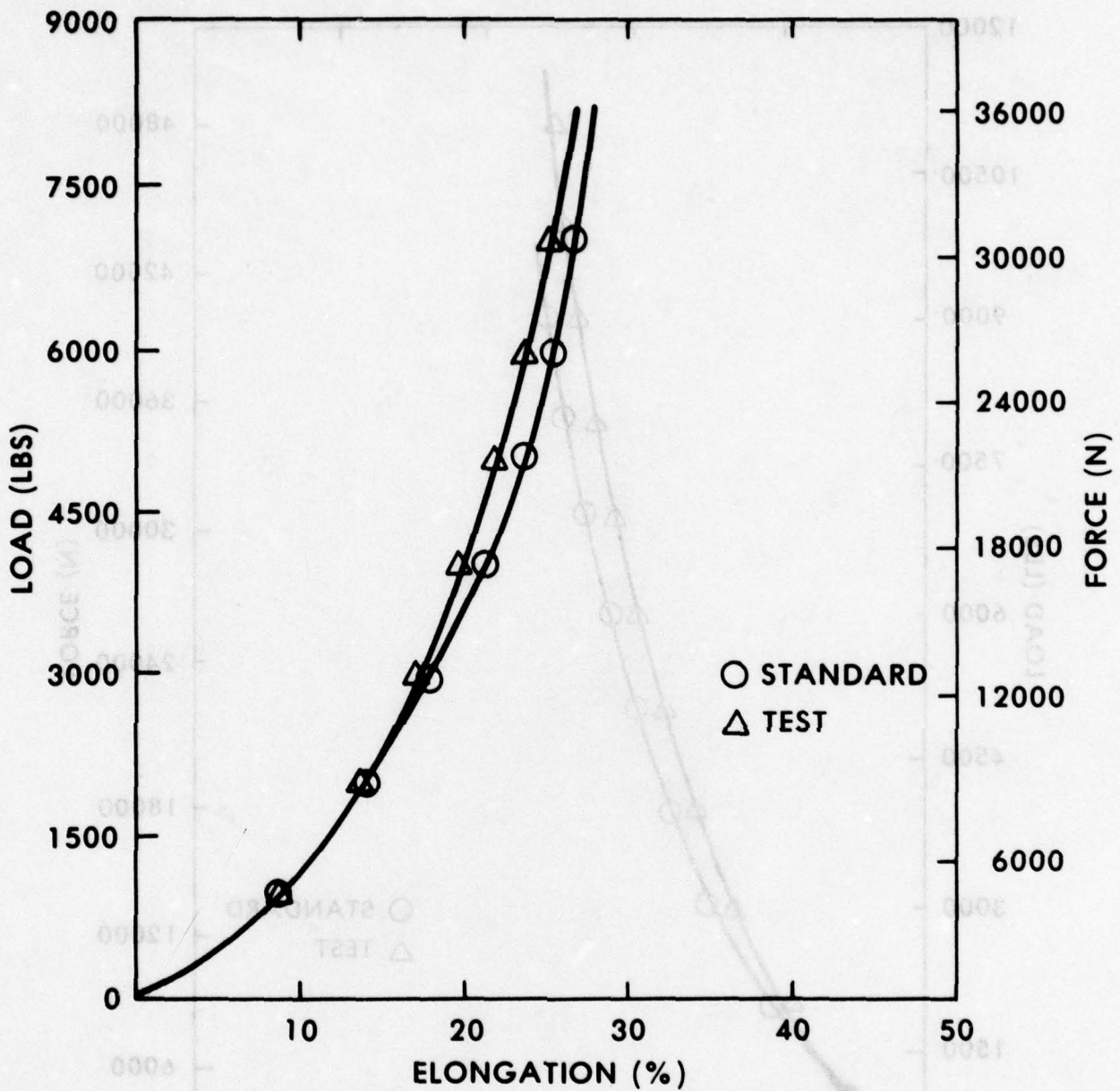


**FIGURE 8 AVERAGE LOAD-ELONGATION CURVE FOR MIL-W-4088H, TYPE VIII STANDARD AND TEST WEBBINGS, 1 3/4-INCH (44 mm) WIDE, CLASS R**

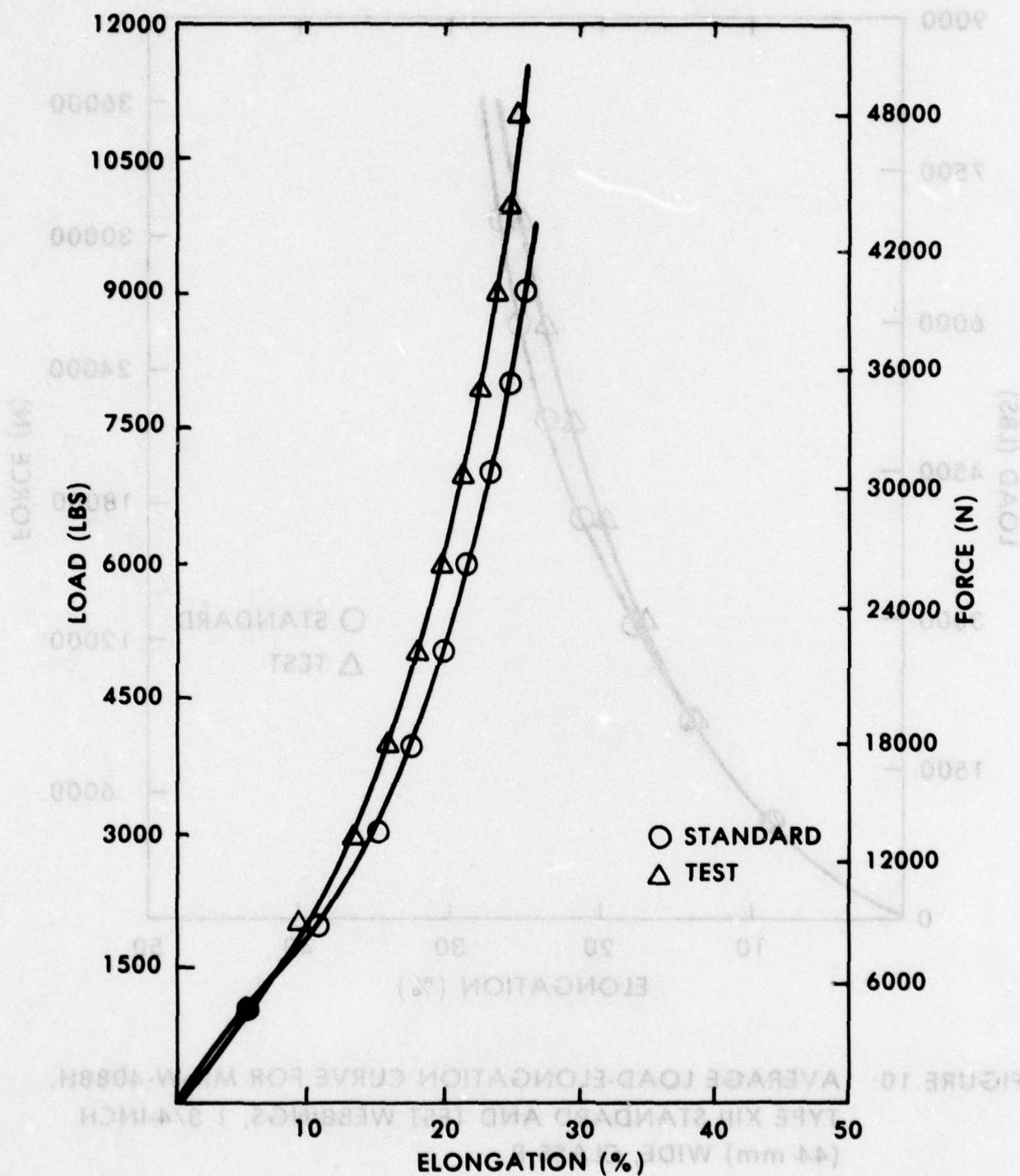


**FIGURE 9** AVERAGE LOAD-ELONGATION CURVE FOR MIL-W-4088H, TYPE XII STANDARD AND TEST WEBBINGS, 1 3/4-INCH (44 mm) WIDE, CLASS R

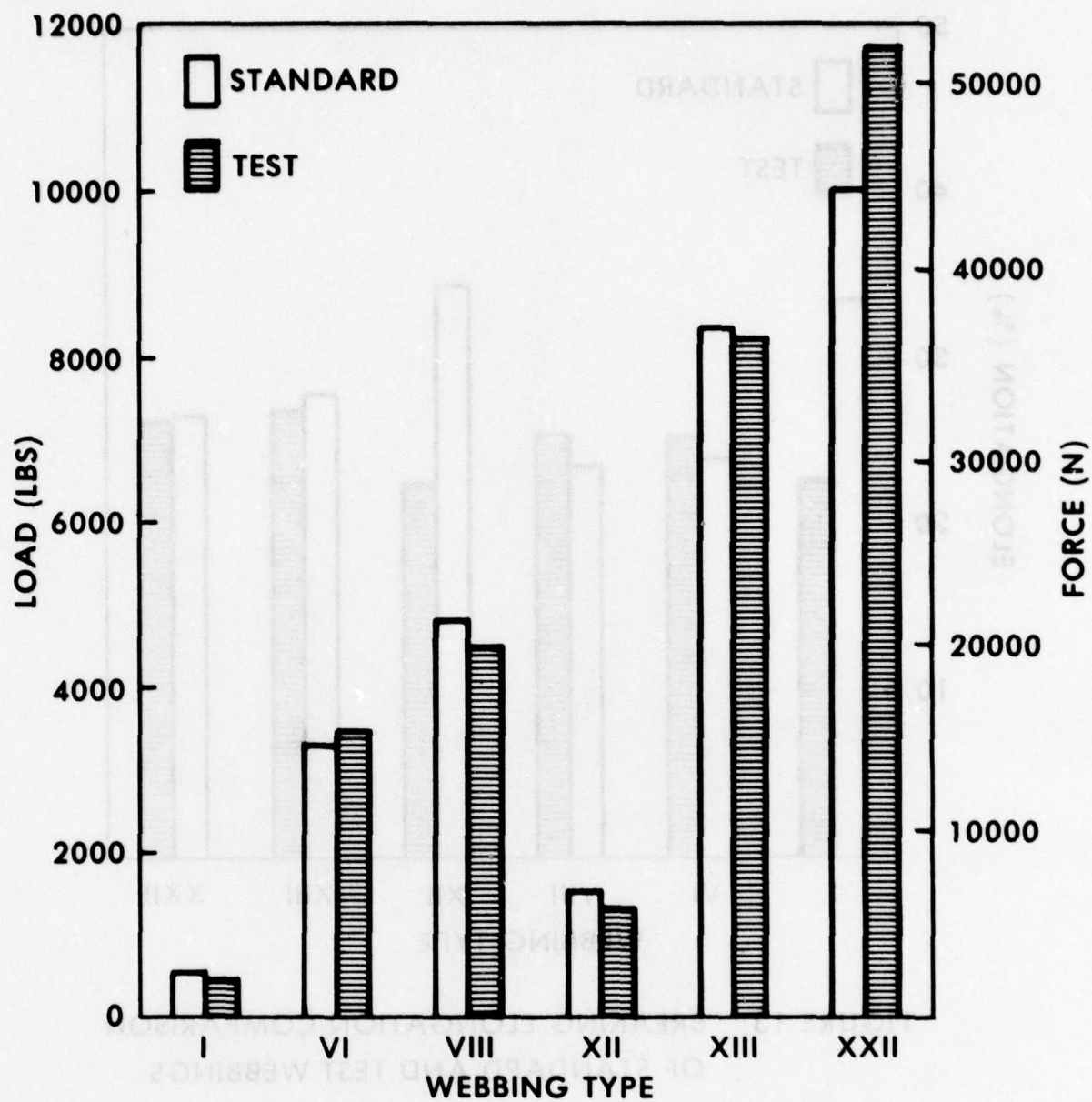




**FIGURE 10** AVERAGE LOAD-ELONGATION CURVE FOR MIL-W-4088H, TYPE XIII STANDARD AND TEST WEBBINGS, 1 3/4-INCH (44 mm) WIDE, CLASS R

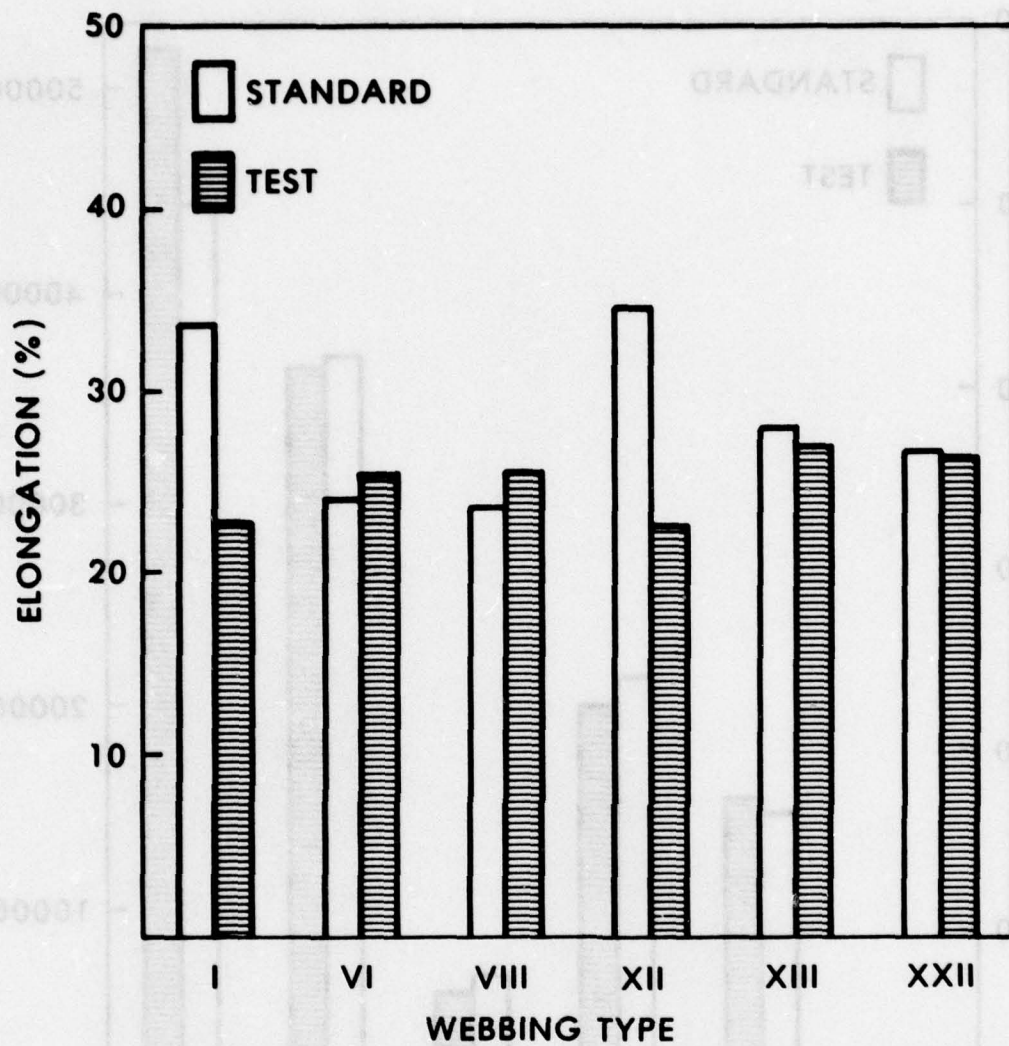


**FIGURE 11 AVERAGE LOAD-ELONGATION CURVE FOR MIL-W-4088H, TYPE XXII STANDARD AND TEST WEBBINGS, 1 3/4-INCH (44mm) WIDE, CLASS R**

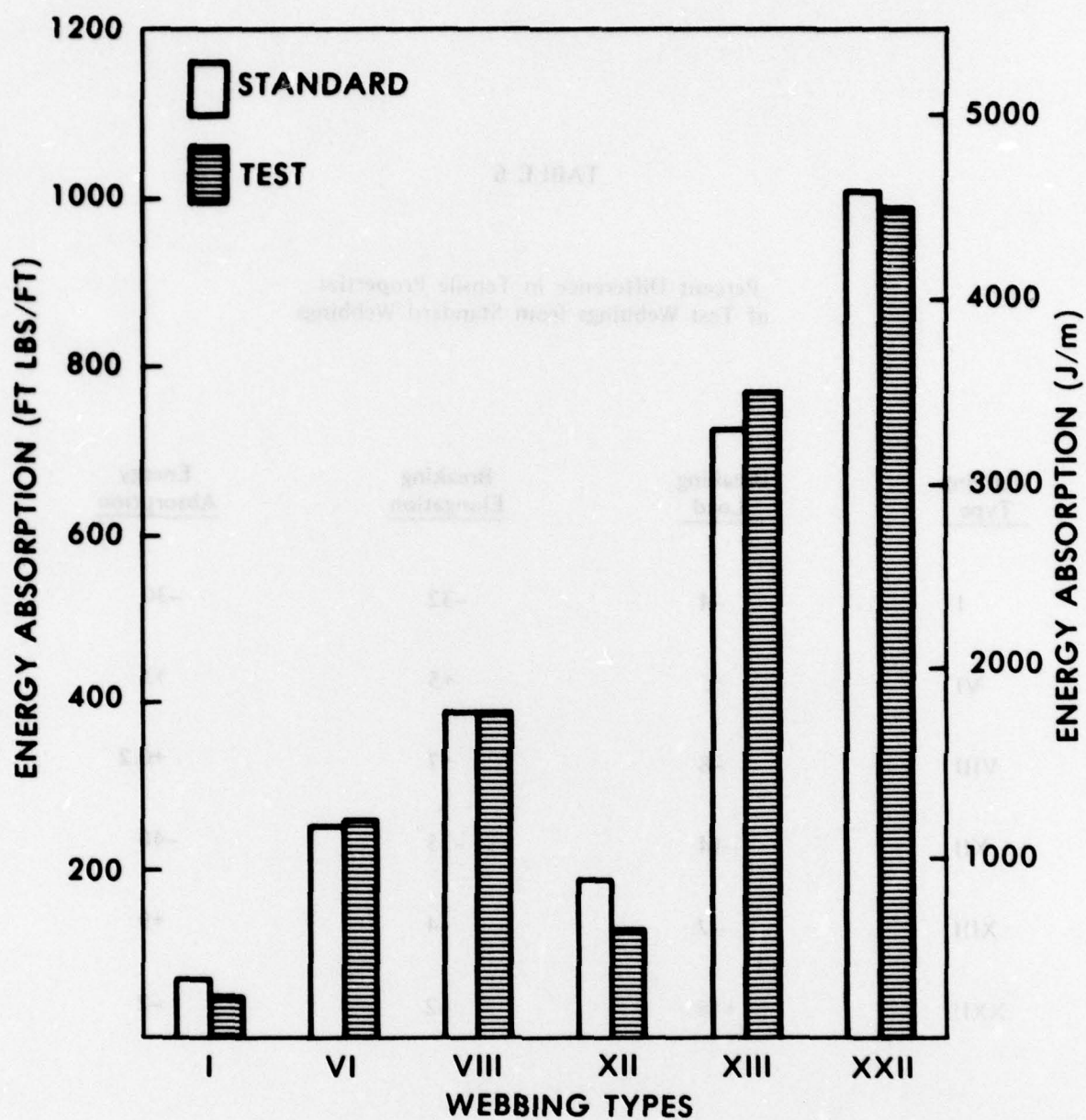


**FIGURE 12 BREAKING LOAD COMPARISON OF STANDARD AND TEST WEBBINGS**





**FIGURE 13    BREAKING ELONGATION COMPARISON  
OF STANDARD AND TEST WEBBINGS**



**FIGURE 14 ENERGY ABSORPTION COMPARISON OF STANDARD AND TEST WEBBINGS**

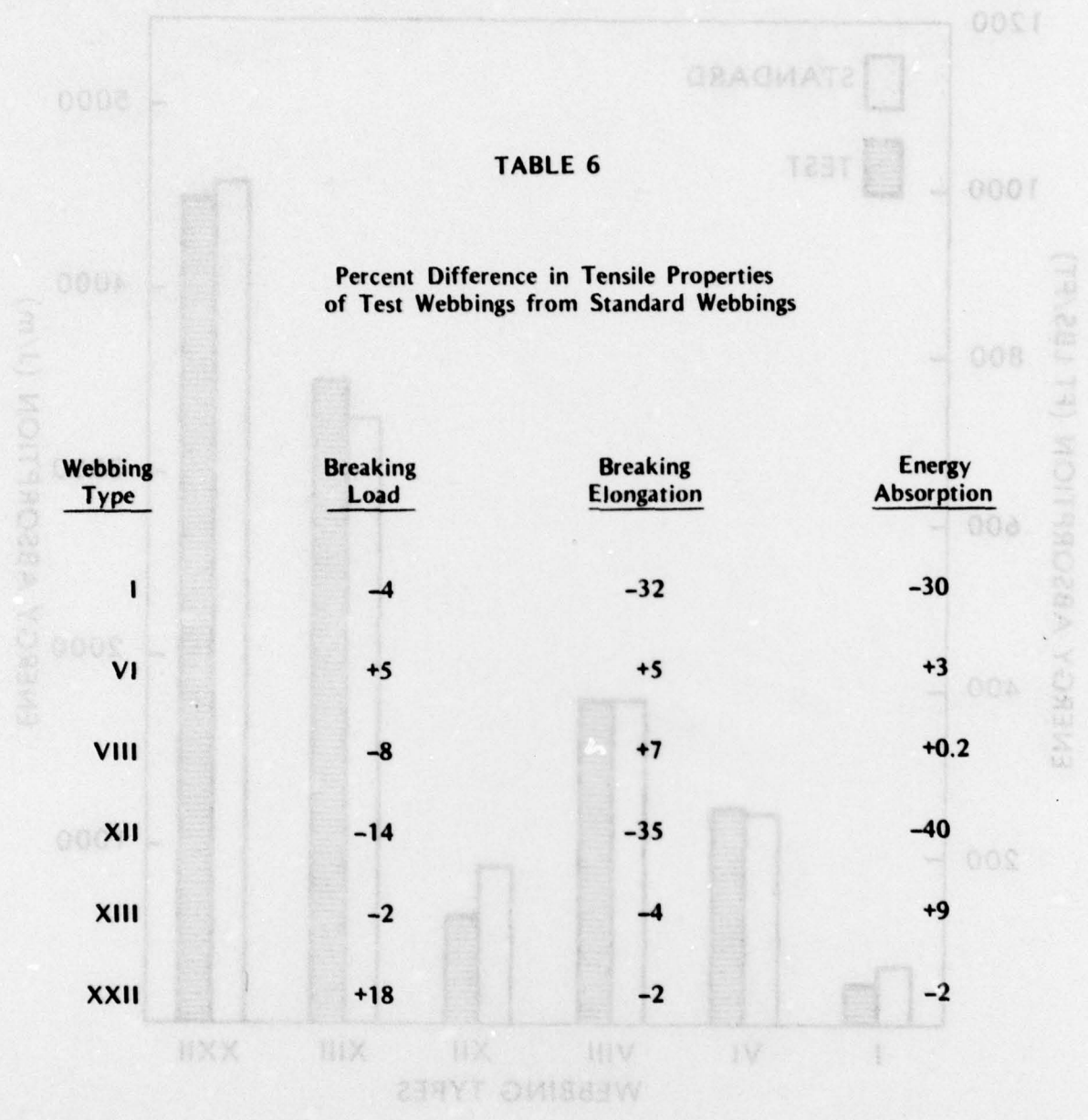
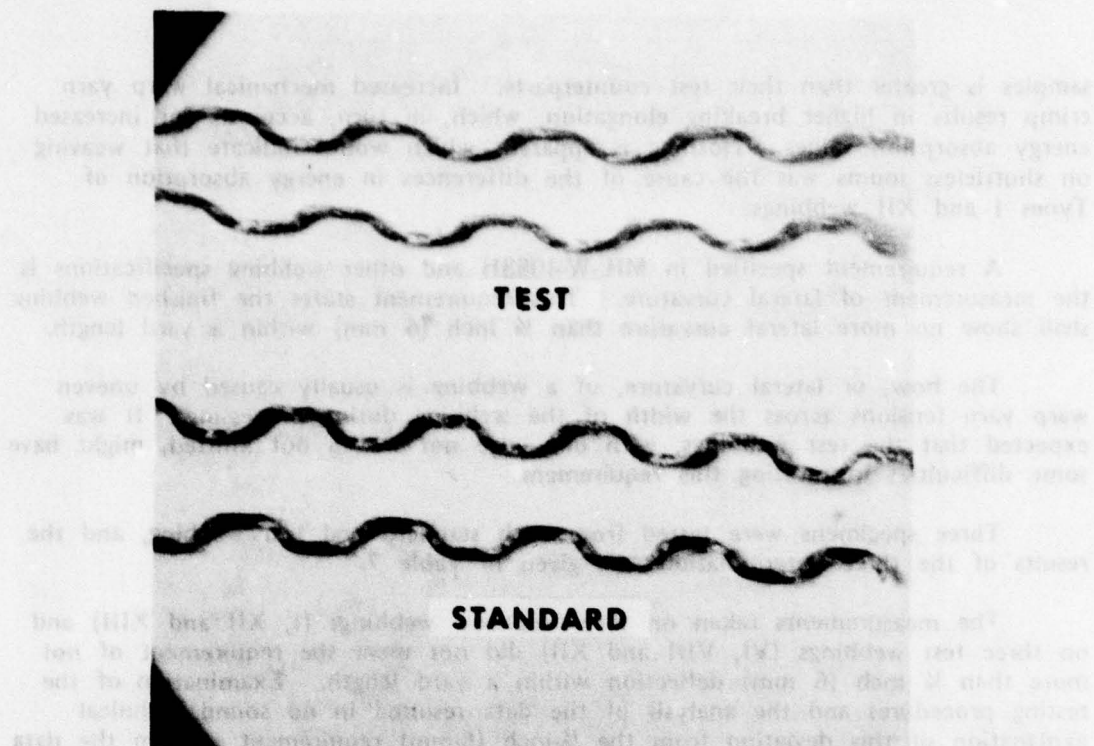
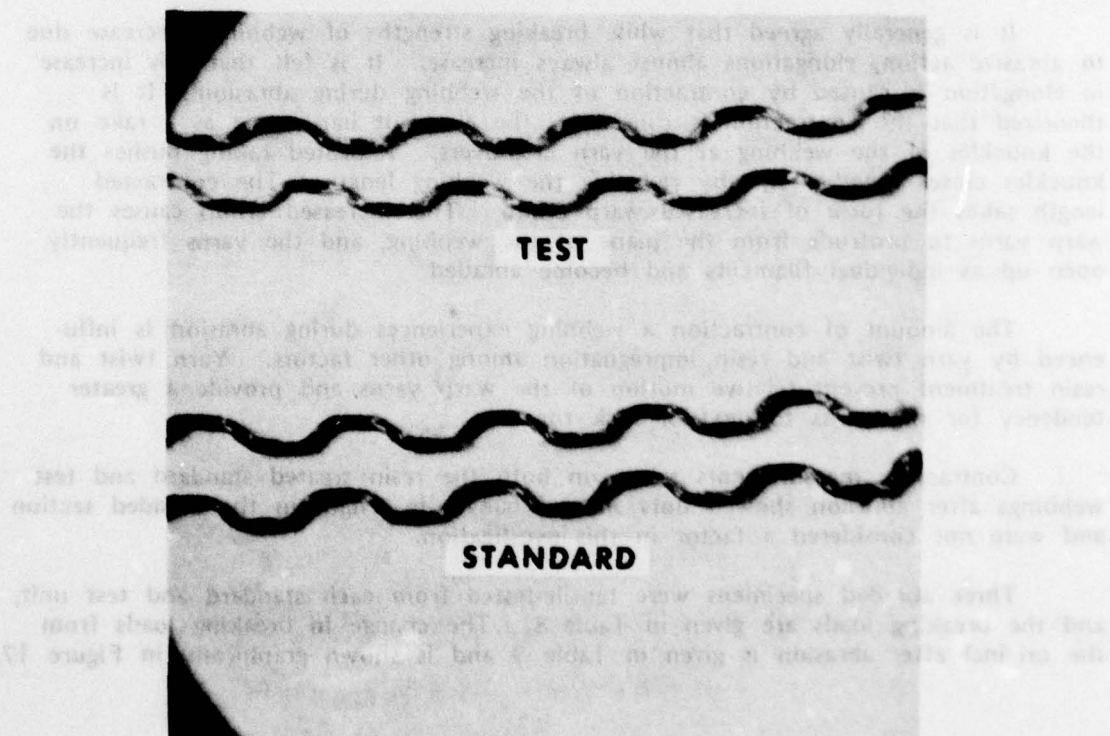


FIGURE 14 ENERGY ABSORPTION COMPARISON OF STANDARD AND TEST WEBBINGS





**FIGURE 15 PHOTOMICROGRAPH (22X) OF WARP YARNS FROM TYPE I WEBBINGS**



**FIGURE 16 PHOTOMICROGRAPH (22X) OF WARP YARNS FROM TYPE XII WEBBINGS**

samples is greater than their test counterparts. Increased mechanical warp yarn crimp results in higher breaking elongation, which, in turn, accounts for increased energy absorption values. Nothing is apparent which would indicate that weaving on shuttleless looms was the cause of the differences in energy absorption of Types I and XII webbings.

A requirement specified in MIL-W-4088H and other webbing specifications is the measurement of lateral curvature. This requirement states the finished webbing shall show no more lateral curvature than  $\frac{1}{4}$  inch (6 mm) within a yard length.

The bow, or lateral curvature, of a webbing is usually caused by uneven warp yarn tensions across the width of the webbing during processing. It was expected that the test webbings, with one edge not woven but knitted, might have some difficulties in meeting this requirement.

Three specimens were tested from each standard and test webbing, and the results of the three determinations are given in Table 7.

The measurements taken on three standard webbings (I, XII and XIII) and on three test webbings (VI, VIII and XII) did not meet the requirement of not more than  $\frac{1}{4}$  inch (6 mm) deflection within a yard length. Examination of the testing procedures and the analysis of the data resulted in no sound technical explanation of this deviation from the  $\frac{1}{4}$ -inch (6-mm) requirement. From the data generated, it can be concluded that the test webbings are comparable to the standard webbings in this characteristic. Also, the deviation in lateral curvature of the test webbings can not be attributed to their knitted edge.

It is generally agreed that while breaking strengths of webbings decrease due to abrasive action, elongations almost always increase. It is felt that this increase in elongation is caused by contraction of the webbing during abrasion. It is theorized that the contraction is caused by the abradant bar acting as a rake on the knuckles of the webbing at the yarn crossovers. Repeated raking pushes the knuckles closer together thereby reducing the webbing length. The contracted length takes the form of increased warp crimp. This increased crimp causes the warp yarns to protrude from the plane of the webbing, and the yarns frequently open up as individual filaments and become abraded.

The amount of contraction a webbing experiences during abrasion is influenced by yarn twist and resin impregnation among other factors. Yarn twist and resin treatment prevent relative motion of the warp yarns and provide a greater tendency for the yarns to nest or lock together.

Contraction measurements taken on both the resin treated standard and test webbings after abrasion showed only minor changes in length in the abraded section and were not considered a factor in this investigation.

Three abraded specimens were tensile-tested from each standard and test unit, and the breaking loads are given in Table 8. The change in breaking loads from the original after abrasion is given in Table 9 and is shown graphically in Figure 17.

TABLE 7

## Lateral Curvature Characteristics of Webbing

<u>Standard Webbing</u>		<u>Test Webbing</u>	
<u>Curvature in 32nds of an inch</u>		<u>Curvature in 32nds of an inch</u>	
<u>Type I</u>		<u>Type I</u>	
	12		4
	14		2
	8		4
Average	11.3 (9 mm)		3.3 (3 mm)
<u>Type VI</u>		<u>Type VI</u>	
	0		8
	0		12
	0		18
Average	0		12.7 (10 mm)
<u>Type VIII</u>		<u>Type VIII</u>	
	4		14
	3		9
	0		8
Average	2.3 (2 mm)		10.3 (8 mm)
<u>Type XII</u>		<u>Type XII</u>	
	8		8
	18		10
	14		8
Average	13.3 (11 mm)		8.7 (7 mm)
<u>Type XIII</u>		<u>Type XIII</u>	
	24		0
	20		0
	22		6
Average	22.0 (18 mm)		2.0 (1.5 mm)
<u>Type XXII</u>		<u>Type XXII</u>	
	8		0
	8		0
	0		8
Average	5.3 (4 mm)		2.7 (2 mm)



TABLE 8

Breaking Loads of Webbing  
After Abrasion

<u>Standard Webbing</u>		<u>Test Webbing</u>	
<u>Breaking Load lb (N)</u>		<u>Breaking Load lb (N)</u>	
<u>Type I</u>			
140		490	
200		490	
220		520	
Average	187 (830)		500 (2220)
<u>Type VI</u>			
2950		3150	
3000		3100	
2950		3250	
Average	2967 (13200)		3167 (14090)
<u>Type VIII</u>			
4600		4600	
4500		4500	
4400		4400	
Average	4500 (20020)		4500 (20020)
<u>Type XII</u>			
1440		1240	
1560		1420	
1620		1300	
Average	1540 (6850)		1320 (5870)
<u>Type XIII</u>			
7300		6100	
7300		6100	
7100		6200	
Average	7233 (32190)		6133 (27290)
<u>Type XXII</u>			
9800		10800	
9800		11000	
8800		9800	
Average	9467 (42130)		10533 (46870)

TABLE 9

Percent Change in Breaking Loads of Webbing After Abrasion

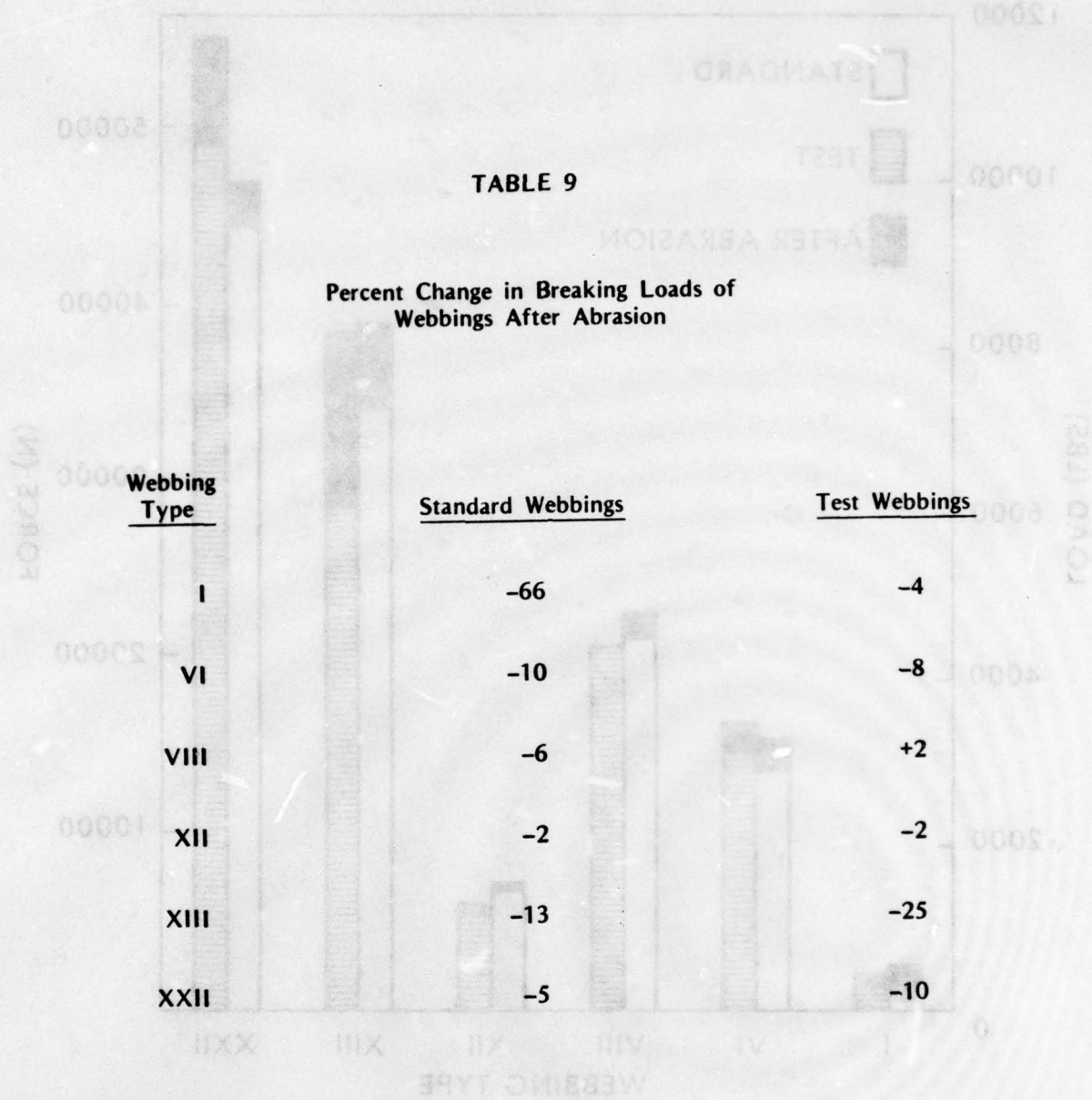
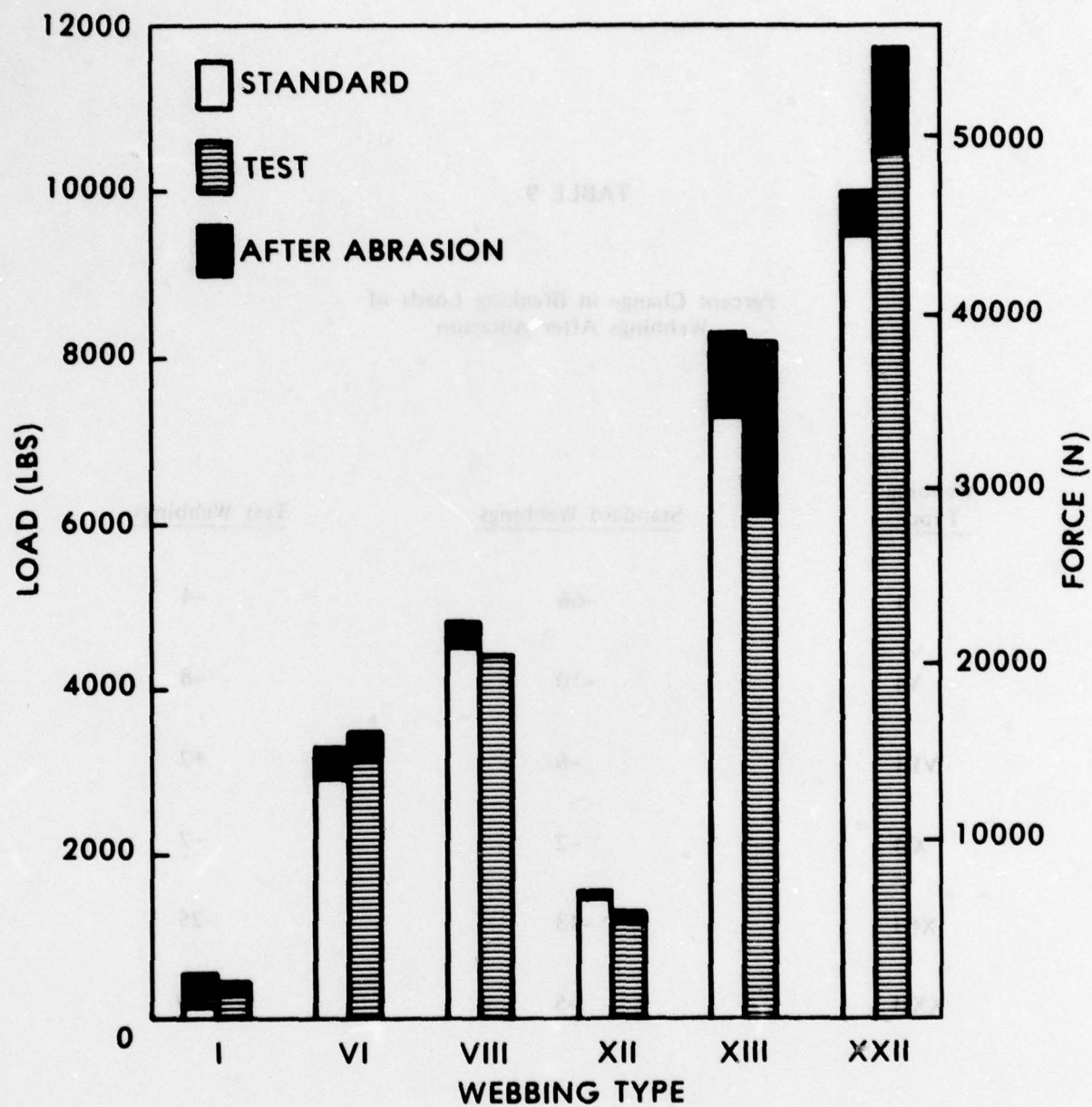


FIGURE 17 EFFECT OF ABRASION ON WEBBING BREAKING LOAD



**FIGURE 17 EFFECT OF ABRASION ON WEBBING BREAKING LOAD**



All test webbings compare favorably to their standard counterparts in breaking load after abrasion. The Type I standard webbing exhibited an unusually high percent loss in breaking load after abrasion due to an unexplained cause. The percent loss in breaking loads of the Type XIII and Type XXII test webbings after abrasion were double that of their standard counterparts, however, the increased percent loss could not be traced to the fact that they were woven on shuttleless looms.

The abrasion resistance of all the webbing samples reported are based on the strength loss after 2500 cycles or 5000 strokes of abrasion. This number is a requirement in MIL-W-4088H and is probably an arbitrary and convenient choice. For some non-resin treated webbings, the strength loss after this degree of abrasion could be in the neighborhood of 40 to 50 percent, beyond which the webbings are of little practical value. However, all webbings in this investigation were resin-treated, and, as stated previously, this increases abrasion resistance.

Data are available which show that most damage takes place relatively early in the abrasion test cycle. In theory, it is possible for two webbings to have the same unabraded original strength and the same percent strength loss after 2500 cycles, yet one will have a much longer useful service life than the other because the rate of strength loss may be different. Thus, the relationship between the number of abrasion cycles and strength loss should be plotted for each sample before a series of webbings can be justly ranked. Unfortunately, this procedure was much beyond the scope of this investigation.

The US Air Force contracted to design and construct a device capable of rupturing high strength components of up to 10,000 pounds (44500 N) breaking strength at impact speeds between 200 and 700 feet per second (60 and 200 m/s). This device has been used in the past to determine the impact behavior of textile structures in use or contemplated for use by the Air Force. It has proven helpful in assessing the potential value of commercial and experimentally produced materials, particularly with regard to their energy absorbing capabilities at high strain rates. As part of this investigation, it was felt imperative to determine the high strain rate response of comparable webbings woven on shuttle looms and shuttleless looms. FRL, Dedham, MA, where the USAF impact tester is housed, was contracted to determine the impact energy absorption characteristics of the standard and test webbings.

Three specimens were tested at a gage length of 5 feet (1.5 m) for each of the standard and test webbings. These data are shown in Table 10. Also given are the striking velocity of the missile and the mass of the missile.

Table 11 shows the percent change in energy absorption at high strain rates from Instron strain rates for each of the webbings characterized.

In assessing the impact performance of parachute components (webbings, cords), energy absorption is no doubt the single most important property to consider. Other considerations are impact modulus, impact breaking load, and impact breaking elongation. Impact energy absorption has been a measurable quantity for some time, while these other parameters have not been, until recently,

TABLE 10

## Impact Energy Absorption Characteristics

Missile Weight lb (g)	Standard Webbing	
	Striking Velocity ft/sec (m/s)	Impact Energy ft lb/ft (J/m)
<u>Type I</u>		
0.97 (440)	213 (65)	59
	212 (65)	57
	209 (64)	59
	Avg	59 (262)
<u>Type VI</u>		
4.08 (1850)	207 (63)	218
	207 (63)	238
	194 (59)	229
	Avg	228 (1014)
<u>Type VIII</u>		
4.08 (1850)	252 (77)	343
	251 (77)	346
	246 (75)	338
	Avg	342 (1521)
<u>Type XII</u>		
3.05 (1380)	213 (65)	178
	199 (61)	197
	204 (62)	201
	Avg	192 (854)
<u>Type XIII</u>		
11.68 (5300)	180 (55)	627
	190 (58)	649
	186 (57)	651
	Avg	642 (2856)
<u>Type XXII</u>		
11.68 (5300)	225 (69)	1084
	200 (61)	1162
	222 (68)	1325
	Avg	1190 (5293)

TABLE 10 (Cont'd)

Test Webbing		
Missile Weight lb (g)	Striking Velocity ft/sec (m/s)	Impact Energy ft lb/ft (J/m)
<u>Type I</u>		
0.97 (440)	203 (62)	34
	202 (62)	34
	201 (61)	35
		<u>34</u>
	Avg	34 (151)
<u>Type VI</u>		
4.08 (1850)	193 (59)	251
	176 (54)	228
	217 (66)	260
		<u>246</u>
	Avg	246 (1094)
<u>Type VIII</u>		
4.08 (1850)	244 (74)	375
	249 (76)	347
	231 (70)	372
		<u>365</u>
	Avg	365 (1624)
<u>Type XII</u>		
1.82 (825)	217 (66)	116
	205 (62)	117
	212 (65)	117
		<u>117</u>
	Avg	117 (520)
<u>Type XIII</u>		
11.68 (5300)	200 (61)	699
	199 (61)	736
	201 (61)	713
		<u>716</u>
	Avg	716 (3185)
<u>Type XXII</u>		
11.68 (5300)	220 (67)	1251
	222 (68)	1221
	220 (67)	1234
		<u>1235</u>
	Avg	1235 (5494)



TABLE 11

Percent Difference in Energy Absorption  
at High Strain Rates from Low Strain Rates

Webbing Type	Energy Absorption Change	
	Standard	Test
I	-12	-28
VI	-10	-5
VIII	-11	-5
XII	+2	+4
XIII	-10	-7
XXII	+18	+25

available to the fabric designer. Recently developed techniques yield complete impact stress-strain information; however, the method is time consuming and expensive. The impact testing technique used in this investigation (pendulum technique) continues to be of great value as a screening tool of potential load bearing components on the basis of impact rupture energy.

The changes in energy absorption at high strain rates of the test webbings are comparable to the standard webbings, with the exception of Type I. The Type I test webbing exhibited a reduction of 28 percent in energy absorption as a result of testing at high strain rates. An examination of the ruptured webbings and discussions with the contractor who performed the testing resulted in no firm conclusion as to the cause of this reduction. However, it was agreed and there is no evidence to indicate the contrary, that this reduction in impact energy is not a result of being woven on a shuttleless loom.

## CONCLUSIONS

1. All of the test webbings met the requirements given in MIL-W-4088H for breaking load.
2. Four of the six test webbings showed breaking elongations comparable to the standard webbings under quasi static conditions. The Type I and Type XII test webbings showed significantly lower breaking elongation and energy absorption when compared to their standard counterparts. This difference is due to the higher level of elongations exhibited by Type I and Type XII standard webbings in relation to the other four standard webbings. These higher elongations also reflected higher energy absorption capacities for these webbings. It was determined that processing variables caused the Type I and Type XII standard webbings to show unusually high levels of elongations.
3. Both the standard and test webbings showed lateral curvatures beyond the requirement in some types. In the case of the test webbings this curvature could not be related to the knitted edge.
4. When subjected to the conventional webbing abrasion test the strength losses of both the standard and test webbings under quasi static conditions were comparable with one exception. The Type I standard webbing exhibited an unusually high percent strength loss after abrasion. This could not be explained.
5. The differences in energy absorption capacity of the test webbing when tested at impact speeds, are comparable to those of the standard webbings except for Type I test webbing which exhibited a reduction of 28 percent.
6. The test webbings are equal in all important respects to the currently used webbings and from all indications should perform equally well in all non-life support military applications. However, further field tests are required to determine the usefulness of shuttleless webbings in critical life support military applications.
7. Based on the current prices, a cost savings of approximately 5 percent could be expected when using shuttleless webbings. In addition, use of shuttleless webbings in critical military applications will broaden the base of supply of nylon webbing.